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SPREAD OF DWARF MISTLETOE from discrete seed sources into young stands of ponderosa and Jeffrey pines

J. R. Parmeter, Jr. Robert F. Scharpf

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Abstract: The maximum distance of spread of dwarf mistletoes from isolated overstory pines into surrounding reproduction averaged 120 feet. The rate of infection in young trees declined as distance from the seed source increased and was generally greatest in the direction of prevailing winds. This pattern of infection was similar to the previously reported pattern of seed dispersal. Each isolated, mature pine infected with dwarf mistletoe provided inoculum to infest about 1 acre of pine reproduction. Such residual trees left after fire or logging should be removed.

Oxford: 442.1:176.1 *Arceuthobium campylopodum*–181.523 [+ 174.7 *Pinus jeffreyi* + 174.7 *Pinus ponderosa*].
Retrieval Terms: Arceuthobium campylopodum; seed dispersal; forest damage; *Pinus jeffreyi; Pinus ponderosa.*

Proper management of forest stands infested with dwarf mistletoe requires knowledge of the distance and pattern of spread from infected overstory trees into young stands. Substantial information is available on spread of *Arceuthobium americanum* in lodgepole pine *(Pinus contorta)*:[1] Spread in ponderosa pine *(P. ponderosa)* is less well understood. Initial infection by *A. vaginatum* f. *cryptopodum* in the Southwestern United States seldom exceeded 60 feet from overstory seed sources, and wind did not influence the pattern of spread.[2] Furthermore, the logarithmic slope of seed deposition curves ended at about 50 feet from the seed source, with an abrupt drop in slope. But *A. campylopodum* infecting ponderosa and Jeffrey pines *(P. jeffreyi)* in California[3] spread 125 to 145 feet. In Oregon, maximum spread was 130 feet and followed prevailing wind patterns; heavy infection was concentrated within 33 feet of the overstory.[4]

Because of these discrepancies and because information on spread under California conditions is needed to provide guidelines for the management of infested stands, we did a study of spread from discrete overstory seed sources.

METHODS

Eleven plots for this study were selected by the criteria: (a) predominantly ponderosa or Jeffrey pine or both species, (b) discrete overstory sources of dwarf mistletoe, and (c) adequate numbers of understory trees around the mistletoe seed sources. Seven of the 11 plots were in Shasta County. Two were in El Dorado County. Nine plots were on old burns where isolated overstory trees had survived. Heavy stands of Manzanita *(Arctostaphylos* spp.*)*, which followed burning, had been partially cleared by bulldozers, and the areas were planted to ponderosa pine in the late 1930's and early 1940's. Some natural

regeneration of Jeffrey pine was also present. Heavy brush competition had markedly suppressed many understory trees, as indicated by average heights *(table 1)*. The remaining two plots—one in Plumas County, the other in Nevada County—were in natural regeneration that followed clearing.

Table 1—*Plot location, height of dwarf mistletoe infection, and of understory and overstory trees in ponderosa and Jeffrey pine stands, northern California*

Plot location and No.	Height of overstory trees	Highest dwarf mistletoe infection	Understory trees sampled	Average height of understory trees
	Feet	*Feet*	*No.*	*Feet*
Shasta County:				
1	([1])	130	160	7.5
2	([2])	109	248	6.5
3	91	90	40	10.6
4	112	100	53	15.1
5	120	100	31	10.0
6	135	125	64	11.7
7	124	109	197	3.9
El Dorado County:				
1	([3])	([3])	200	9.5
2	([3])	([3])	125	20.0
Plumas County	110	108	34	10.0
Nevada County	65	50	90	6.8

[1]Height of three trees: 90, 100, and 134 feet.
[2]Height of two trees: 124 and 128 feet.
[3]Overstory trees cut before the study. Examination of crown remains indicated heavy infection high in the crowns, but exact heights could not be determined. Stumps were 30 to 36 inches in diameter.

Plots were centered on residual overstory trees occurring singly or in compact groups of two or three trees. All understory trees were accurately located and mapped, and the height of each tree and the amount of mistletoe were recorded. Ponderosa and Jeffrey pines were considered together, with no attempt to record data separately.

All plots were level or moderately sloping. Because of irregularities in ground cover and the distribution of small trees, few of the plots were ideally circular. Several plots included trees only in one general direction from the source of infection. We could not, therefore, obtain a complete sample on all plots, but all trees within the limits of the mapped sectors were recorded. These sectors represent a random sample with respect to size, distance from seed source, and amount of infection. Plot lines on each plot were extended from the stem of the overstory tree to the maximum distance of spread or to 120 feet, which ever was greatest.

Table 2—*Understory trees in each of seven height classes at each of six distance intervals from overstory trees*

Distance interval (feet)	Understory height classes (feet) . . .						
	0-5	5.1-10	10.1-15	15.1-20	20.1-25	25.1-30	30+
	Percent						
0-20	81	14	4	1	0	0	0
21-40	59	28	6	2	3	1	1
41-60	49	21	8	10	6	4	1
61-80	38	33	8	9	3	4	4
81-100	34	39	13	7	4	2	2
101-120	37	31	11	9	5	3	5
All intervals	44	30	9	7	4	3	2

Data were tabulated by 20-foot zones from the stem of the seed source tree. Since distance of maximum spread determined plot limits and was less than 140 feet on all plots, we analyzed data only to the most distant complete zone—120 feet.

RESULTS

Infection In Relation To Understory Tree Height

Height-class distributions were not uniform with respect to distance from the source trees *(table 2)*. Trees 10 feet and under constituted 74 percent of all trees sampled, but they constituted 95 percent of the trees at 0 to 20 feet from the source trees, and 87 percent of the trees 21 to 40 feet from the source. Conversely, few tall trees were found within 40 feet of the source tree. Beyond 40 feet, height distributions did not appear to be markedly influenced by overstory trees. Average tree heights among the plots ranged from 3.9 to 20 feet *(table 1)*.

Pooled data from 11 plots show the relationship of understory tree height to infection *(table 3)*. In trees up to 15 feet tall, infection increased as tree height increased. In larger trees, this relationship was obscured because few large trees were found near the seed source, where high rates of infection would be expected.

Distance From Seed Source In Relation To Infection

The graphed slope of decline *(table 3; fig. 1)* in the percent of 0- to 10-foot trees infected at increasing distances was similar to the slope of decline in seed deposition found in previous seed trapping studies.[4] When larger trees were included, a flatter slope of decline was obtained, apparently reflecting the increase in numbers of large trees farther from the overstory trees. The rate of infection remained relatively high even at 101 to 120 feet.

lodgepole pine stands was farther than that from stand margins (45 as opposed to 28 feet averages). If similar differences occur with ponderosa and Jeffrey pines, average spread from stand margins might be considerably less than that from isolated trees. To find out further study is warranted.

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NOTES

[1]Gill, Lake S., and Frank G. Hawksworth. *Dwarfmistletoe of lodgepole pine.* Forest Pest Leafl. 18, 7 p. 1964.

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[2]Gill, Lake S. *Dwarfmistletoe of ponderosa pine in the Southwest.* U.S. Forest Serv., Rocky Mt. Forest & Range Exp. Stn. Paper 14, 9 p. 1954.

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[3]Scharpf, R. F., and J. R. Parmeter, Jr. *Spread of dwarf mistletoe into Jeffrey pine plantation. . .trees infected after 22 years.* U.S. Forest Serv. Res. Note 141. Pacific SW. Forest & Range Exp. Stn., Berkeley, Calif. 6 p. 1967.

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Roth, L. F. *Pine dwarfmistletoe on the Pringle Falls Experimental Forest.* U.S. Forest Serv., Pacific NW. Forest & Range Exp. Stn. Res. Note 9, 3 p. 1953.

[5]Scharpf, Robert F. *Dwarf mistletoe on red fir—infection and control in understory stands.* USDA Forest Serv. Res. Paper PSW-50. Pacific SW. Forest & Range Exp. Stn., Berkeley, Calif. 8 p. 1969.

[6]Kimmey, J. W. *Dwarfmistletoes of California and their control.* U.S. Forest Serv., Calif. Forest & Range Exp. Stn. Tech. Paper 19, 12 p. 1957.

The Authors

J. R. PARMETER, is professor of plant pathology at the University of California, Berkeley. He earned a bachelor's degree in botany at Oregon State University (1951) and a doctorate in plant pathology at the University of Wisconsin (1955). **ROBERT F. SCHARPF,** a plant pathologist, is studying problems in forest diseases and their control. He earned a forestry degree (1954) at the University of Missouri, and a master's degree in forestry (1957) and a doctorate in plant pathology (1963) at the University of California, Berkeley. He joined the Forest Service in 1960, and has been with the Station's Berkeley research staff since then.

analyzing differences in the direction of spread. These plots had also been used for a 4-year study of seed dispersal.[4] The pattern of spread could therefore be compared to the pattern of seed dispersal. Eight 45° sectors were centered on the same compass lines used to orient seed traps in the earlier study *(fig. 2)*. The percent infection in the NW, N, NE, and E sectors was two to six times that in the SE, S, SW, and W sectors. Of the remaining nine plots, the two showing the shortest distances of maximum spread (90 and 103 feet) had understories only to the south.

DISCUSSION

Precise determination of infection rates at various distances from discrete sources of mistletoe seed ideally requires uniform levels of inoculum and understory trees of even size, age, and spacing. Uneven survival of planted trees, random natural regeneration, inherent differences in growth rates, and overstory suppression of nearby regeneration virtually preclude finding or creating ideal plots. Furthermore, the rate of infection is low in small trees, and before a level of infection sufficient for analysis develops, it is likely that some secondary buildup from understory infections will have occurred. For these reasons, field data provide a basis only for general statements of relationships and for probable mathematical expressions of these relationships.

The pattern of infection from a discrete overstory seed source should reflect the pattern of decrease in seed deposition at increasing distances from the source. When only small trees are considered, infection curves approach the slope of the deposition curve *(fig. 1)*, and such slopes probably would be similar under ideal circumstances. When trees of all sizes are considered, the slope of the infection curve is flatter than that of the seed deposition curve. This divergence is apparently associated with unequal distribution of size-classes at various distances from the overstory.

Larger understory trees are more likely to be infected either because they present a larger target for seed interception or because they are older and therefore have been exposed to inoculum for longer periods than have smaller or younger trees.[2,4,5] Our data and those of Gill[2] and Hawksworth and Graham[1] indicate that suppression by overstory trees reduces the density and height of nearby understory trees. Thus, as the amount of seed deposition decreases with distance from the overstory, the size and density of understory trees tends to increase,

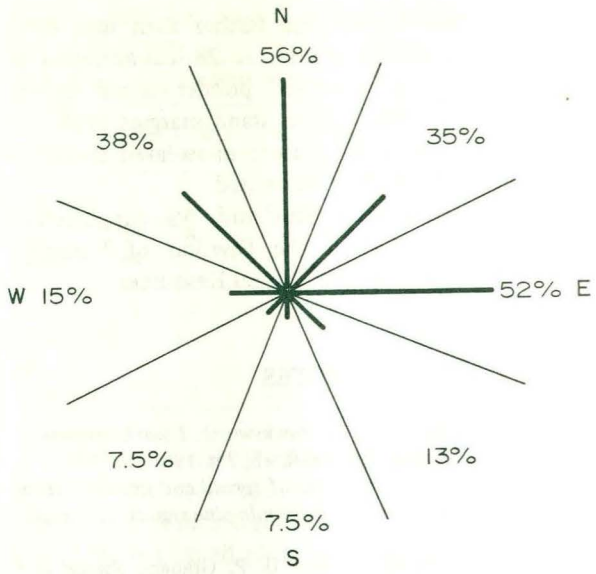

Figure 2—The percent of trees infected in each of eight 45° sectors was highest in the north and east sectors.

leading to greater opportunity for infection and also to greater likelihood of additional secondary infections. These factors appear to account for the divergence of the slopes of seed deposition and infection curves.

We found no abrupt decrease either in rate of infection or in seed deposition in the California areas studied. Both deposition and infection declined regularly to the limits of the distances considered. Our data indicated, however, that an abrupt drop in the rate of infection must occur between 120 and 135 feet, since the maximum spread did not exceed 135 feet.

Our results confirm Roth's[4] findings that wind influences the pattern of spread. The amount of infection in generally northerly directions was several times that in southerly directions and followed prevailing wind and seed deposition patterns.[3]

Data on spread from discrete seed sources have implications in the management of ponderosa and Jeffrey pine stands in California. Each isolated, mature pine infected with dwarf mistletoe provides inoculum to infest about one acre of pine reproduction. Such residual trees left after fire or logging should be removed. Initial spread into young stands will likely exceed that suggested by Kimmey,[6] since on five of nine plots for which tree heights were available, maximum spread exceeded overstory tree heights by 6 to 63 feet. These data may not apply to stand margins, however, Muir[1] found that spread from isolated trees or small groups of trees in

Table 3—*Trees infected with dwarf mistletoe, by height class and distance from seed source*

Height class (feet)	Distance from seed source (feet) . . .												Total infected trees	Total infection
	0-20		21-40		41-60		61-80		81-100		101-120			
	No.	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*
0-5	30	45	20	22	16	14	4	4	11	11	2	3	83	15
5.1-10	8	67	24	56	25	49	25	28	24	20	9	15	115	31
10.1-15	3	100	6	67	10	53	11	50	18	47	9	43	57	51
15.1-20	1	100	2	67	16	64	21	84	8	38	11	61	59	63
20.1-25	0	–	2	50	10	67	4	50	8	67	4	40	28	57
25.1-30	0	–	2	100	8	80	6	60	2	40	2	40	20	63
30.1+	0	–	0	–	1	50	4	36	2	40	7	78	14	50
All trees	42	51	56	36	86	36	75	28	73	24	44	22	–	–

Distances of maximum spread on the 11 plots *(table 4)* averaged 120 feet. Maximum spread exceeded the height of overstory trees by 6 to 63 feet on five plots and was less by 1 to 32 feet on four plots. Source tree heights were unavailable on two plots.

The maximum spread distances recorded might be a result of secondary spread within the understory as well as of primary spread from the overstory. Opportunity for secondary spread was evaluated by recording the numbers of infections in understory trees *(table 4)*, since numerous infections in single understory trees would suggest secondary build-up and thus increased opportunity for secondary spread.

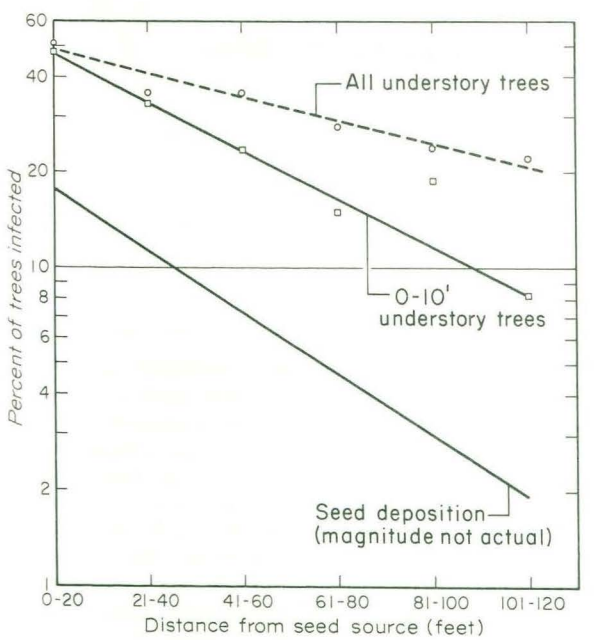

Figure 1—Percentage of 0 to 10 foot trees infected, the percentage of all understory trees infected, and seed deposition (from Scharpf and Parmeter 1971) in relation to distance from overstory trees.

On two plots (maximum spread: 128 and 130 feet), there were no heavily infected trees—a sign of no appreciable production of mistletoe seed in the understory. On four plots, heavily infected trees were present, but were not in a position or direction to provide inoculum for the most distant infections. On four plots, heavily infected trees might have contributed to maximum spread; however, average distance of spread on these plots (120 feet) did not differ appreciably from that (117 feet) on the six plots where secondary inoculum was not involved.

Direction of Spread

Only two of the 11 plots were sufficiently circular and had rates of infection suitable for

Table 4—*Infections per tree and maximum spread of dwarf mistletoe on the 11 plots in ponderosa and Jeffrey pine stands, northern California*

Plot location and No.	Infections per tree . . .					Maximum spread
	1-2	3-5	6-10	11-20	21+	
	No. trees					*Feet*
Shasta County:						
1	39	9	8	5	0	124
2	40	11	6	4	1	118
3	2	1	0	1	1	[1]90
4	14	8	1	3	4	[1]118
5	10	2	1	1	1	[1]135
6	11	2	1	0	0	[1]103
7	8	0	0	0	0	[1]130
El Dorado County:						
1	53	22	14	3	1	117
2	25	7	4	6	4	122
Plumas County	17	1	0	0	0	[1]128
Nevada County	([2])					135

[1]Maximum spread was not associated with or in the direction of any heavily infected understory trees.

[2]Data on this plot were recorded on a rating scale rather than by actual numbers.

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